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ON THE CULTURAL TRANSMISSION OF CORRUPTION

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Abstract

We provide a cultural explanation to the phenomenon of corruption in the framework of an overlapping generations model with intergenerational transmission of *values*. We show that under reasonable parameters the economy has two steady states which differ in their levels of corruption. The driving force in the equilibrium selection process is the education effort exerted by parents which depends on the initial distribution of *ethics* in the population and on expectations about policies in the future. We propose some policy interventions which via parents' efforts have long lasting effects on corruption and show the success of intensive education campaigns. We argue that our model explains the differences which are observed across countries with similar degrees of economic development and that educating the young is a key element in reducing corruption successfully.

Keywords: corruption, cultural transmission, overlapping generations, principal-agent.

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On the cultural transmission of corruption

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We provide a cultural explanation to the phenomenon of corruption in the framework of an overlapping generations model with intergenerational transmission of *values*. We show that under reasonable parameters the economy has two steady states which differ in their levels of corruption. The driving force in the equilibrium selection process is the education effort exerted by parents which depends on the initial distribution of *ethics* in the population and on expectations about policies in the future. We propose some policy interventions which via parents' efforts have long lasting effects on corruption and show the success of intensive education campaigns. We argue that our model explains the differences which are observed across countries with similar degrees of economic development and that educating the young is a key element in reducing corruption successfully.

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1 Introduction

Mohammedans are Mohammedans because they are born and reared among the sect, not because they have thought it out and can furnish sound reasons for being Mohammedans; we know why Catholics are Catholics; why Presbyterians are Presbyterians; why Baptists are Baptists; why Mormons are Mormons; why thieves are thieves; why monarchists are monarchist; why Republicans are Republicans and Democrats, Democrats. We know that it is a matter of association and sympathy, not reasoning and examination; that hardly a man in the world has an opinion on morals, politics, or religion that he got otherwise than through his associations and sympathies

Mark Twain.

Recent scandals in Japan, Italy and Spain show that corruption is not an exclusive phenomenon of underdeveloped countries. Countries with similar degrees of development exhibit enormous differences in the levels of corruption. Models linking corruption solely with the degree of economic development cannot explain these facts. Nor are they fully captured by institutional differences. Incentive and punishment schemes for corrupt activities certainly influence the level of corruption, but a given scheme does not work equally well in all countries. This suggests that corruption may be due, at least in part, to cultural elements.

This paper focuses on the cultural transmission of corruption and develops policy measures which can reduce corruption within this framework. Different attitudes towards corruption are incorporated into preferences as a moral cost due to the feeling of guilt. For simplicity, we assume that there are just two types of agents: *honest* "moral" agents and *potentially dishonest* agents who only care about monetary payoffs. The crucial point of this paper is that while these values are transmitted from one generation to the next, the incentives of parents to shape their offsprings' attitudes towards corruption depend on economic factors.

The idea that morality enters into agents' preference ordering via feelings stretches back to Arrow (1967) and has been often used in the context of corruption (e.g. Rose-Ackerman (1978), Chinn (1978), Block and Heinecke (1975), Andvig and Moene (1990), Besley and McLaren (1993), Qizilbash (1994)).¹ Typically, two modeling techniques are used: (i) the *conformist approach* incorporates moral feelings directly into the utility function. (ii) The *lexicographic approach* incorporates moral considerations by the use of lexicographical preferences. In this case morality enters discontinuously since it only matters in cases of indifference on other grounds. The present paper follows the tradition of the conformist approach. It goes beyond existing models by explicitly recognizing the implicit assumption that morality is a result of socialization².

The intergenerational transmission of knowledge, values, and other factors that influence behaviour plays an important role in the evolution of societies. Cultural traits, such as the attitudes towards immigrants or the environment, ethics in the work place, or looking left and right before crossing a street become part of the phenotype of an individual and are very likely to be transmitted by learning and imitation. In this paper we

¹This idea is supported by a number of psychological, sociological and experimental studies (see e.g. Coursey *et al.* (1987) and Frank (1988)).

²Akerlof (1983) already recognized that education influences honesty.

focus in the intergenerational transmission of attitudes against corruption, incorporating both vertical transmission, with offsprings learning from their parents, and oblique transmission, with offsprings learning from some member of the parent's generation (see Boyd and Richerson (1985)). Cavalli-Sforza and Feldman (1982) provide evidence for vertical transmission of cultural traits such as religious beliefs, political attitudes, the frequency of praying and attending the church, sportive practices, the frequency of listening to classical music, salt usage...etc. LeBras and Todd (1981) hypothesize that family structure strongly influences political beliefs. Phenomena like the Mafia seem to have their origin in societies where families are strong institutions and children are exposed, from the very beginning, to a homogenous set of cultural models in the family (Cavalli-Sforza (1996)).

An example of the influence of oblique transmission on corruption levels is Hong Kong where public attitudes against corruption changed drastically in the last decades due to the Independent Commission Against Corruption (ICAC) and especially its community relations department. The main emphasis of the ICAC education program was to "build a strong altruism and a sense of responsibility in oneself and toward the others", de-emphasizing the importance of getting money and getting ahead at the expenses of the others (Clark (1987)). Some empirical studies point out that the perception of corruption as a social problem in Hong Kong depends to some extent on age (and therefore on the time the different groups were exposed to the ICAC). For instance, in 1986, 75.1% of the 15-24 age group (which had been subject to the ICAC's education program for about 13 years) believed that corruption was a social problem whereas only 54% of the 45-64 age group (who were born and lived their formative years when the ICAC didn't exist) agreed with that.

Vertical and oblique transmission are incorporated into our theory by assuming that ethics against corruption are transmitted via education. The transmission model is similar to Bisin and Verdier (1996). A simple overlapping generation model with principal-agent relation, rational expectations and random matching is postulated. In each period, infinitely lived principals are randomly matched to the agents. At any time period an agent may give birth to a child who will become active in the next period. During the rearing period the parent has to educate his child.³ (Stochastic death keeps the population constant). Parents care about their children and want to maximize their child's well-being. However, given that they do not know what is best for their child, they evaluate their child's welfare as if it were their own⁴. Following Bisin and Verdier (1996) the cultural parent chooses the "coefficient of cultural transmission", or the education effort i.e, the probability with which the parent's cultural trait is adopted by the child. When the child does not "learn" from the parent, he imitates a randomly chosen member of the parent's generation. In this world, if education were free, parents would choose to transmit their preferences with probability 1 and the society wouldn't evolve. If education in the family

³Although asexual reproduction is not a good representation of the biological world in which reproduction is mostly sexual, it might be a good approximation to the evolution of cultural traits. When the transmission takes place between parents and offspring (vertical transmission), although both parents contribute to the cultural traits inherited by the offspring, it may happen that some traits are transmitted in a uniparental way (religion seems to be transmitted exclusively by the mother). The relation teacher-pupil is another example of a single cultural parent.

⁴Alternatively, the model could be interpreted as parents caring about their child's behaviour or parents caring about the survival of their own preferences.

were prohibitively expensive, new agents would follow a "conformist" learning mechanism, and the spread of the most frequent trait would be observed. The higher the education effort, the smaller the importance of this *frequency-dependent bias* (Boyd and Richerson (1985)).

In our model, as in a typical principal-agent model, corruption exists because of asymmetric information and costly monitoring. In our information structure each principal knows the exact proportion of dishonest players in the population and has some (imperfect) information about the honesty of the agent he is facing. There is no information leakage across principals.

Our basic principal-agent model is related to Tirole (1996). In each period a principal has to assign a project to the agent he is randomly matched with. There are two types of projects. Project 1 is socially better than project 2 if managed with honesty. The reverse is true if the agent behaves dishonestly. The projects can be interpreted as two different public investments, one more costly than the other and with a higher social return if managed correctly. This project, by involving a larger amount of money, is more susceptible to corruption (selection of worse materials, manipulation of allocation mechanism such as auctions...). Think for instance of project 1 as the construction of new roads and project 2 as resources devoted to the maintenance of existing ones.

We show that under reasonable parameters both types of agents choose positive transmission coefficients. This implies that any stable steady state is interior and that corruption is never eliminated completely as long as some corrupt behaviour existed in the past. We show that under rational expectations there are two pure strategy steady states. In the *low corruption steady state*, the principals offer project 1 to all agents for whom there is no evidence of corrupt behaviour and project 2 to all those agents for whom such evidence exists. In the *high corruption steady state* only project 2 is offered. In this case the existence of dishonest players exerts a negative externality on the honest players. The general suspicion prevents honest people from getting good projects.

The steady states are related to Tirole's (1996) whose model has three types of agents in fixed proportions, *honest*, *dishonest* and *opportunistic agents*. Which steady state arises depends on whether or not opportunists choose to be honest. While both models serve to illustrate how collective reputation can outweigh individual reputation (or vice versa) thereby affecting the overall corruption level of society, Tirole's model cannot provide a convincing explanation why countries with the same level of development and similar institutions nevertheless may have drastically different levels of corruption. In his model cultural attitudes exist in fixed proportions and cannot change over time. The present paper does provide an answer to the above question. Cultural attitudes evolve endogenously and which steady state is reached is history-dependent. Three parameter regimes are distinguished: (i) the high corruption steady state is reached always, (ii) the low corruption steady state is reached always and (iii) one of the steady states is reached depending on initial conditions. (i) and (ii) result from extremely poor or nearly perfect monitoring technologies of principals. Therefore, it seems a reasonable guess to assume that most countries are likely to be in (iii).

For the latter case the paper develops some temporary policy measures in order to permanently manipulate the cultural transmission coefficients. The advantages and disadvantages of each measure are discussed. Two time consistent policy measures with

long lasting effects on the level of corruption are proposed. The first policy consists of a temporary increase in the monitoring expenditure and, consequently, in the accuracy of the information gathered by the principals. Such a policy can drive the economy out of the high corruption steady state into the basin of attraction of the low corruption equilibrium. In the second policy the principals announce at t that they will give project 1 from period $t + k$ onwards to everybody with a clean record. This announcement (commitment) increases the future value of being honest above the one of being dishonest and the proportion of honest agents starts increasing in $t + 1$. We show that there exists a k (which depends on the parameters of the model) such that such a policy is optimal. The policy announcement triggers a change in the education efforts exerted by the different types of parents which makes the policy announcement time consistent. We also discuss the effect of (temporary) public education campaigns and show that they successfully reduce the level of corruptions if and only if they are intensive enough, i.e. if the public education effort is high enough. This condition seems to have been satisfied in the case of Hong Kong.

The paper is organized as follows. In section 2 we introduce the model and characterize the steady states. Policy implications are spelt out in section 3 and the effects of public education campaigns are discussed. Section 4 concludes.

2 The model

We propose a principal-agent model similar to Tirole's (1996). We consider a random matching model where each agent can never meet the same principal twice. At each time t ($-\infty < t < \infty$) every active agent is matched with a new principal. The principal gives the agent one of 2 projects. Project 1 yields a higher payoff to the principal than project 2 if the agent is honest, but is more susceptible to corrupt behaviour. The payoffs to the principal are

$$H > h \geq d > D$$

where capital letters denote the payoffs to the principal if project 1 is given. H stands for honest and D for dishonest behaviour by the agent.

Agents can be of two types: honest or potentially dishonest. The payoffs to an honest agent are as follows

honest type		
	Project 1	Project 2
honest	B	b
dishonest	$\bar{B} - e$	$\bar{b} - e$

With $B, \bar{B}, b, \bar{b}, e > 0$ and

$$e > \bar{B} - B \geq \bar{b} - b \geq 0. \quad (1)$$

If (1) holds, honest agents always behave honestly. Observe that an honest agent suffers from being dishonest. He is endowed with a *moral attitude* which favours "honest" behaviour. On the contrary, potentially dishonest agents only care about monetary payoffs,

potentially dishonest type		
	Project 1	Project 2
honest	B	b
dishonest	\bar{B}	\bar{b}

Under (1) dishonest behaviour is a dominating strategy in the one shot game. Thereafter, since we assume that (1) holds, we shall refer to potentially dishonest players as dishonest.

The model is a model of overlapping generations. A Poisson birth and death process is assumed. An active agent in t has a child with probability $(1 - \lambda)$. The child is educated by the parent and becomes active in $t + 1$. With probability λ an active agent will be active next period. Observe that the population size of active players is constant. We can think for example of a situation in which there is some turnover in the job and newcomers are trained by people with experience. The crucial assumption is that an agent does care about his offsprings' welfare and when deciding how much effort to put into his child's education evaluates his child's utility through his own eyes. In other words he uses his payoff matrix as if it were his child's, like in Bisin and Verdier (1996).

The education process works as follows: The parent educates his naive child with some education effort τ . With probability equal to the education effort, education will be successful and the child will be like his parent. Otherwise, the child remains naive and gets randomly matched with somebody else whose preferences he will adopt. Consider an honest agent who has a child at time t and chooses education effort τ^a and let P_t^{ij} be the probability that a child of parent i is of type j

$$P_t^{aa} = \tau_t^a + (1 - \tau_t^a)q_t \quad (2)$$

$$P_t^{ab} = (1 - \tau_t^a)(1 - q_t) \quad (3)$$

where q_t is the proportion of honest agents at time t . Similarly, for the dishonest parent we get

$$P_t^{bb} = \tau_t^b + (1 - \tau_t^b)(1 - q_t) \quad (4)$$

$$P_t^{ba} = (1 - \tau_t^b)q_t \quad (5)$$

where τ^b is the dishonest parents' education effort.

2.1 The education choice

Let $C(\tau)$ be the cost of the education effort τ and assume that $C(0) = 0$, $C' > 0$ and $C'' > 0$.

A parent of type i chooses the education effort $\tau \in [0, 1]$ that maximizes

$$P_t^{ii}V_t^{ii} + P_t^{ij}V_t^{ij} - C(\tau) \quad (6)$$

where P^{ij} and P^{ii} are defined above and V^{ij} is the utility a parent with preferences i attributes to his child having preferences j . In order to assess V^{ij} a parent of type i uses his own payoff matrix. Therefore $V^{ii} > V^{ij}$ always. Notice that V^{ij} is an expected utility

and depends on the policy expectations of the parent. Maximizing (6) with respect to τ we get the following first order condition

$$C'(\tau^i) = \frac{dP^{ii}}{d\tau^i} V^{ii} + \frac{dP^{ij}}{d\tau^i} V^{ij} \quad (7)$$

where we have suppressed the time indicators.

Substituting (2)-(5) in (7) we get the optimal education efforts τ^a and τ^b ,

$$C'(\tau^a) = [V^{aa} - V^{ab}](1 - q) \quad (8)$$

$$C'(\tau^b) = [V^{bb} - V^{ba}]q \quad (9)$$

In order to have interior solutions $\tau \in (0, 1)$ we need that $C'(0) = 0$ and that $C'(1) > \bar{B}/(1 - \lambda)$, which is the upper bound to agents' payoffs. From (8) and (9) it follows that the optimal effort level is $\tau = \tau(q)$ with

$$\frac{d\tau^a(q)}{dq} = -\frac{V^{aa} - V^{ab}}{C''(\tau^a(q))} < 0 \quad \text{and}$$

$$\frac{d\tau^b(q)}{dq} = \frac{V^{bb} - V^{ba}}{C''(\tau^b(q))} > 0.$$

Since $V^{ii} - V^{ij}$ depends on the parent's policy expectations, so does the optimal effort level τ .

We can now characterize the dynamic behaviour of q_t :

$$q_{t+1} = F(q_t) = \lambda q_t + (1 - \lambda)(q_t P_t^{aa} + (1 - q_t) P_t^{ba})$$

substituting (2) and (5) and suppressing the time subscripts, we obtain

$$F(q) = \lambda q + (1 - \lambda)[(\tau^a(q) + (1 - \tau^a(q))q)q + (1 - \tau^b(q))q(1 - q)]$$

which can be rewritten as

$$F(q) - q = (1 - \lambda)q(1 - q)(\tau^a(q) - \tau^b(q)) \quad (10)$$

Observe that (10) has three rest points: i) $q = 0$, ii) $q = 1$ and iii) $q = q^*$,

$$q^* = \frac{V^{aa} - V^{ab}}{V^{bb} - V^{ba} + V^{aa} - V^{ab}} \quad (11)$$

with $\tau^a(q^*) = \tau^b(q^*)$.

Lemma 1 Assume that $C''(\tau) \geq C'(\tau) > 0$ for all $\tau \neq 0$, $C'(0) = 0$ and $C'(1) > \max_i V^{ii} - V^{ij}$, $V^{aa} - V^{ab} > 0$ and $V^{bb} - V^{ba} > 0$. The only stable rest point is q^* .

Proof. See appendix.

2.2 The principals' choice

Each period a principal has to decide what project to delegate on the agent he is matched with. We assume that principals maximize their expected payoffs and that they know the proportion of honest agents in the population but not the type of a particular agent. As in Tirole (1996) we assume that the principal has some imperfect information about each agent's past behaviour: with probability α he knows if the agent has been dishonest at least once in the past. Hence, the principal either observes a clean or a dirty record. An honest agent will never be revealed as dishonest. Moreover, there is no information leakage across principals⁵. If one principal observes an agent with a dirty record it can still be the case that in the future the same agent is taken for an honest one. Given this information structure, if it pays to be dishonest once it pays to be always dishonest. As dirty records cannot be cleaned, the probability of being discovered as a dishonest agent is the same independently of the times one agent has been dishonest.

Let σ^s be the *separating strategy* consisting of offering project 1 to agents with a seemingly clean record and project 2 to agents with a dirty record. Assume that principals follow strategy σ^s , then potentially dishonest player will behave dishonestly if

$$\frac{B}{1-\lambda} < \bar{B} + \lambda \frac{\bar{B}(1-\alpha) + \bar{b}\alpha}{1-\lambda}. \quad (12)$$

Assume now that (12) holds, then the proportion of corrupt agents with a clean track record is $(1-q)Y$ where Y is the average probability that past corruption activities go unnoticed,

$$Y = (1-\lambda)[1 + \lambda(1-\alpha) + \lambda^2(1-\alpha) + \dots + \lambda^k(1-\alpha) + \dots] = 1 - \lambda\alpha \quad (13)$$

Let σ^p be the *pooling strategy* of offering project 2 to everybody. Principals prefer policy σ^s to σ^p if

$$q(H-h) + (1-q)Y(D-d) > 0 \quad (14)$$

which can be rewritten as

$$q > \tilde{q} = \frac{(1-\lambda\alpha)(d-D)}{(H-h) + (d-D)(1-\lambda\alpha)}. \quad (15)$$

Let $\sigma(q_t)$ denote the principals' optimal policy at time t , namely

$$\sigma(q_t) = \begin{cases} \sigma^s & \text{if } q_t > \tilde{q} \\ \{\sigma^s, \sigma^p\} & \text{if } q_t = \tilde{q} \\ \sigma^p & \text{if } q_t < \tilde{q} \end{cases}$$

2.3 The steady states.

We now characterize the steady states of the economy. The education effort exerted by a parent in t depends on the expectation about the principals' policy in the future. A "policy" is an (infinite) sequence $\{\sigma_z\}_{z=t_1}^\infty$, with $\sigma_z \in \{\sigma^s, \sigma^p\}$, for all z . We will denote

⁵Information leakage across principals does not affect the qualitative results of the paper.

by $\{\sigma^i\}_{t_1}^{t_2}$, the sequence consisting of the repetition of σ^i from t_1 to t_2 ($t_1 < t_2 \leq \infty$). Let $\tau(k_t^e)$ be the education effort of a parent in t who expects a policy $k_t^e = \{\sigma_z\}_{z=t+1}^\infty$ and let $V^{ij}(k_t^e)$ be the expected utility a parent of type i attributes to his child born in t (and active in $t+1$) having preferences j when the expected policy is k_t^e .

Lemma 2 Assume $C'(\tau) > 0$ and that condition (12) holds. Then

1. $\tau^a(\{\sigma^s\}_{t+1}^\infty) > \tau^b(\{\sigma^s\}_{t+1}^\infty)$, when $q_t < \bar{q}$
2. $\tau^a(\{\sigma^p\}_{t+1}^\infty) > \tau^b(\{\sigma^p\}_{t+1}^\infty)$, when $q_t < \underline{q}$
3. $\tau^a(\{\{\sigma^s\}_{t+1}^{T-1}, \{\sigma^p\}_T^\infty\}) > \tau^b(\{\{\sigma^s\}_{t+1}^{T-1}, \{\sigma^p\}_T^\infty\})$, when $q_t < \bar{q} - \lambda^{T-t-1}(\bar{q} - \underline{q})$,
4. $\tau^a(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}) > \tau^b(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\})$,

when $q_t < \underline{q} + \lambda^{T-t-1}(\bar{q} - \underline{q}) + \lambda^{T-t-1}\alpha(1-\lambda)\frac{\bar{B}-\bar{b}}{e}$, where

$$\underline{q} = \frac{e - (\bar{b} - b)}{e} \quad \text{and} \quad \bar{q} = \frac{e + \lambda\alpha(\bar{B} - \bar{b}) - (\bar{B} - B)}{e}.$$

Proof. From (8)-(9) we get that $\tau^a(k_t^e) > \tau^b(k_t^e)$ when

$$q_t < \frac{V^{aa}(k_t^e) - V^{ab}(k_t^e)}{V^{bb}(k_t^e) - V^{ba}(k_t^e) + V^{aa}(k_t^e) - V^{ab}(k_t^e)} \quad (16)$$

Computing the right hand side of (16) for the different expected policy profiles we get the values above. \square

The previous lemma compares the education efforts exerted by the two types of parent for four different expectations, two of them stationary (cases 1 and 2) and two of them involving a policy change at a future date T (cases 3 and 4). Observe that $\bar{q} > \underline{q}$ when

$$\alpha\lambda > \frac{(\bar{B} - \bar{b}) - (B - b)}{\bar{B} - \bar{b}} \quad (17)$$

The average probability that past corruption is not detected has to be small relative to the relative increase in payoffs for honest and dishonest agents under regimes σ^s and σ^p .

Proposition 1 Assume $C''(\tau) \geq C'(\tau) > 0$ for all $\tau, q_0 \neq \{0, 1\}$, (12), (17) hold, principals follow $\sigma(q_t)$ and agents have rational expectations. Then,

1. q_t converges to \bar{q} if $\tilde{q} < \underline{q}$,
2. q_t converges to \underline{q} if $\tilde{q} > \bar{q}$ and
3. when $\underline{q} < \tilde{q} < \bar{q}$
 - (a) q_t converges to \bar{q} if $q_0 > \tilde{q}$ and
 - (b) q_t converges to \underline{q} if $q_0 < \tilde{q}$.

Proof. See appendix .

We refer to \bar{q} and \underline{q} as the *low corruption* and the *high corruption* steady states, respectively⁶.

Observe that the steady state the system converges to depends for cases 1 and 2 on the location of \tilde{q} with respect to \bar{q} and \underline{q} and in case 3, on the initial proportion of honest players. A too inefficient monitoring technique (high \tilde{q}) implies that the low corruption steady state \bar{q} can never be reached. A very efficient technique avoids the high corruption steady state. The smaller \tilde{q} the larger the basin of attraction of \bar{q} . This implies that in a economy with infrequent renewal (large λ) it is easier to reach the low corruption steady state since \tilde{q} decreases with λ . The underlying intuition is that if agents live longer the average probability that past corrupt activities go unnoticed falls. The principals have a more accurate picture of individual behaviour.

3 Policy measures.

Under rational expectations the steady state the system converges to is determined by the relative positions of \bar{q} , \underline{q} and \tilde{q} and in the case in which $\underline{q} < \tilde{q} < \bar{q}$ also by the initial proportion of honest agents. While the position of \underline{q} only depends on the payoff matrices of the agents, \bar{q} and \tilde{q} also depend on the frequency of renewals λ and the accuracy of the principal's information α . Hence, feasible policy measures will have to affect the remuneration to agents or the accuracy of principals' information or agents' expectations⁷. We shall now discuss the advantages and disadvantages of these measures.

Changing the remuneration to the agents will affect equilibrium values directly. An increase in the payoff when agents behave honestly in project 1 (B) and in project 2 (b) increases the equilibrium proportion of honest players in the low and in the high corruption equilibria, respectively. The same is true for a decrease of \bar{B} and \bar{b} . However, principals will face some restrictions when choosing remunerations.. A payoff increase can only be achieved by higher wages and has to be financed somehow. Moreover, higher wages simultaneously increase B (or b) and \bar{B} (or \bar{b}). In order to lower \bar{B} or \bar{b} principals would have to be able to restrict the extent of corrupt activities somehow. This might not always be possible.

A similar problem arises concerning an increase in the accuracy of principals' information α . The choice of α is influenced by technological restrictions. Therefore, unless some new monitoring technology is discovered, it is not reasonable to assume that principals can improve their information forever. Given the technological constraints principals can improve their α only by incurring higher costs which cannot be optimal in the long run because otherwise principals would have operated at these higher costs to begin with. Nevertheless, if $\tilde{q} < \bar{q}$, there is room for a temporary increase in spending on monitoring.

Notice, that an increase in the accuracy of information and thereby in the probability of detecting fraudulent behaviour will shift \tilde{q} to a lower value, will increase the basin

⁶Information leakage across principals would not affect the position of the high corruption steady state. However, given that principals have better information, the basin of attraction of the low corruption steady state would increase as well as the proportion of honest agents in this equilibrium.

⁷We assume that the frequency of renewals cannot be affected by principals.

of attraction of the low corruption steady state and at the same time the proportion of honest behaviour in such an equilibrium. Assume that $\tilde{q} < \bar{q}$ and that there exists an $\bar{\alpha} \in]\alpha, 1]$ such that $q(\bar{\alpha}) = \bar{q}$, then the high corruption steady state can be left by a temporary increase in α . Given $\bar{\alpha}$, the separating strategy σ^s is optimal and people with a clean record will get project 1. By lemma 2 the high corruption steady state will be left if honest agents expect $k_t^e = \{\sigma^s\}_{t+1}^\infty$. The principal can ensure this by reducing spending on monitoring to the original (optimal) level in such a way that $\tilde{q}(\alpha)$ is always smaller than q_t in all periods t .

In the above policy measure principals behave optimally given the accuracy of their information α_t . Therefore, if agents can observe how much principals spent on monitoring the policy measure is perfectly credible. Moreover, this policy is feasible if the temporary increase in spending is off-set by the gains from reaching the low corruption steady state.

By a similar argument, principals could incur a cost by simply giving the good project in a bad environment ($q_t < \tilde{q}$) to stimulate education efforts of honest parents. In other words principals would have to apply the separating policy σ^s despite its being suboptimal over several periods. The latter policy is unlikely to be implemented since principals cannot commit to ignoring their cut-off value \tilde{q} . For this policy to be effective agents would have to believe that principals are willing to behave in a sub-optimal manner. The temporary increase in spending on monitoring differs from simply ignoring the cut-off value since, under the former, the resulting behaviour of principals is optimal given the observed increase in monitoring costs.

All policy measures discussed so far worked by changing some variable which affected agents' expectations and therefore their education efforts. We now consider an alternative policy which affects agents' expectations directly and in which principals always behave optimally by announcing a time consistent policy change in the future.

Assume that the economy is in the high corruption steady state; everybody is getting project 2 independently of their records. In the high corruption steady state no principal has an incentive to give project 1 to anybody, not even if a clean record is observed. Assume now, that at t principals commit to the policy profile $\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}$, namely, they will offer project 2 to everybody (pooling strategy) until time $T - 1$, and from T onwards project 1 will be offered only to those players with clean records (separating strategy). Observe that this is different from an amnesty because sinners are not forgiven⁸.

Lemma 3 Assume that $q_t = \bar{q}$, $C(\tau) = \tau^\beta$, with $\beta \geq 2$, $\alpha \leq \frac{\bar{B}-B}{\bar{B}-b}$ and that parents choose optimally their education efforts given $k_t^e = \{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}$. Then,

$$\tau^a(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}) > \tau^b(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}) \text{ for all } t \in [s, T].$$

Proof. See appendix.

Proposition 2 Assume that conditions of lemma 3 hold, then policy $\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}$ is credible if $q_{T-1} \leq \tilde{q} \leq q_T$

⁸Tirole (1996) considers the possibility of an amnesty. He shows that an amnesty is always detrimental in steady state although it yields a Pareto improvement if society is out of steady state. Notice that in his model our policy measure cannot work, while in our model an amnesty is uninteresting since adults cannot change their preferences.

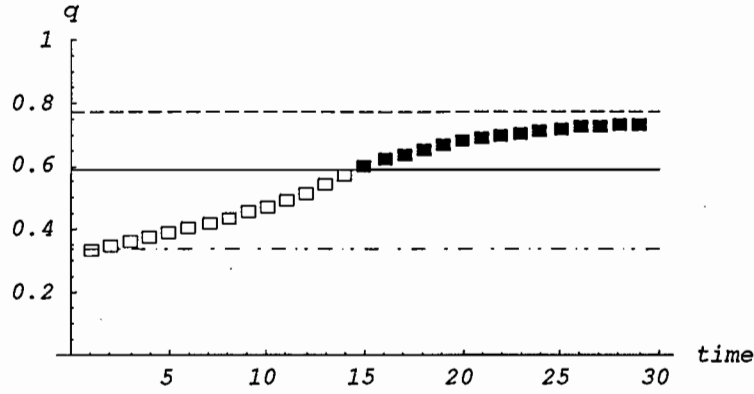


Figure 1: Time consistent policy announcement

Proof. It follows directly from the previous lemma and from the fact that when $q_t \geq \tilde{q}$, $\sigma(q_t) = \sigma^s$. By lemma 2 $\tau^a(\{\sigma^s\}_{t+1}^\infty) > \tau^b(\{\sigma^s\}_{t+1}^\infty)$, and $q_t > \tilde{q}$ for all $t > T$.

Figure 1 is an illustration of proposition 2. The economy is initially in the high corruption equilibrium. The continuous line is the value of \tilde{q} . The announcement of the policy change in $T = 15$ increases the honest parents' effort today and q starts growing. At $T = 14$ the economy has reached the critical value \tilde{q} and from $T = 15$ on it is optimal to start offering project 1 to agents with clean records. This way the society can leave the high corruption equilibrium after the time consistent announcement. The policy announcement is time consistent because at the moment of the change the proportion of honest players in the population is such that (15) is satisfied and σ^s is the optimal policy sequence from then onwards. Observe that by proposition 1, the system converges to the low corruption steady state. The result is driven by the fact that the policy announcement raises the value of being honest more than it increases the value of being dishonest. Honest parents, foreseeing that in the future it will pay to be honest increase their education effort once such a policy is announced.

The above policy measures all aim at affecting the driving force of the population dynamics: the education effort exerted by parents. Moral education is a purely private issue. We shall now analyze the effectiveness of education campaigns in which the existing public education systems are used to emphasize moral values.

In most countries public education does not start immediately when a child is born. Usually, children are exposed to the influence of their parents before undergoing public education. To respect this common education structure we assume that only children who remain naive, i.e. who do not learn their preferences from their parents, can be influenced by public education. An education campaign will be modeled as society (or principals) investing in public moral education by choosing a public effort level ρ to teach honest behaviour at school. Similar to private education efforts, the public education effort represents the probability with which a child who did not learn from his parents adopts honest preferences in school. The new timing of moral education is as follows: as before, the education effort of the parents τ determines the probability with which children adopt

the same preferences as their parents. With the complementary probability $(1-\tau)$ children remain naive in which case the public education effort ρ determines the probability with which children become honest. With the complementary probability public education fails and children meet a random member of society whose preferences they adopt.

Public education affects the probabilities of honest and dishonest children as follows⁹:

$$P_t^{aa} = \tau_t^a + (1 - \tau_t^a)(q_t(1 - \rho) + \rho) \quad (18)$$

$$P_t^{ab} = (1 - \tau_t^a)(1 - q_t)(1 - \rho) \quad (19)$$

$$P_t^{bb} = \tau_t^b + (1 - \tau_t^b)(1 - q_t)(1 - \rho) \quad (20)$$

$$P_t^{ba} = (1 - \tau_t^b)(q_t(1 - \rho) + \rho) \quad (21)$$

The first order conditions which determine the private education efforts are now,

$$C'(\tau^a) = [V^{aa} - V^{ab}](1 - q)(1 - \rho) \quad (22)$$

$$C'(\tau^b) = [V^{bb} - V^{ba}](q(1 - \rho) + \rho) \quad (23)$$

The new population dynamics are given by the following difference equation for q_t :

$$\Delta q = (1 - \lambda)q(1 - q)(\tau^a(q) - \tau^b(q))(1 - \rho) + (1 - \lambda)(1 - q)(1 - \tau^b(q))\rho \quad (24)$$

which can be rewritten as

$$\Delta q = (1 - \lambda)(1 - q) \left[(\tau^a(q) - \tau^b(q))q(1 - \rho) + (1 - \tau^b(q))\rho \right] \quad (25)$$

This difference equation shows that (i) $q = 1$ is always a rest point of the system, (ii) $q = 0$ is only a rest if no public education exists ($\rho = 0$), (iii) if an interior solution exists, the education effort of dishonest parents is higher than of honest parents ($\tau^a < \tau^b$). The introduction of public education has two opposite effects: while its direct effect is to increase the proportion of honest agents, its indirect effect is to change the incentives for private education; honest parents educate less because public education increases the chances of their children getting the right preferences anyway while dishonest parents educate more. Which effect will dominate partly depends on the value of ρ . Notice, that if $\rho=1$ the system converges to $q = 1$ although honest parents do not educate their children at all. Hence, for $\rho = 1$, $\Delta q > 0$ for all $q < 1$. By continuity, there exists a $\bar{\rho}$ such that for $\rho > \bar{\rho}$ $\Delta q > 0$ for all $q < 1$. Indeed, it is easy to see that for $\rho > \tau^b(1)$ $q = 1$ is the only attractor¹⁰.

The above analysis establishes the success of a temporary intensive education campaign with a high enough ρ . Suppose society is in the high corruption steady state and $\tilde{q} < \bar{q}$. The government launches a very intensive education campaign with $\rho > \tau^b(1)$. The campaign affects the population dynamics and the proportion of honest agents increases.

⁹ $\rho = 0$ is identical to the case without public education

¹⁰This is not the cut-off value. A complete analysis of the model becomes very messy and is beyond the scope of the paper. We are only interested in finding some temporary education campaign which is successful.

The education campaign can be stopped once $q_t > \tilde{q}$; by lemma 2 the system converges to the low corruption steady state \tilde{q} .

To summarize, temporary education campaigns will be successful in reducing corruption if they are intensive enough. If ρ is too low, q_t will remain below \tilde{q} and it will not be optimal for principals to switch to the separating policy. Education campaigns work only if the investment in public education is high enough during the period of the campaign and the campaign lasts long enough.

Both conditions seemed to have been satisfied in the case of Hong Kong. The education effort of the Independent Commission against Corruption (ICAC) had been very high and the project lasted a substantial period of time. Moreover, at least in early years, ICAC combined two policy measures discussed in our model: re-education and a change in the remunerations to agents to reduce the profitability of corruption. This combination accelerates the move towards the low corruption steady state.

4 Conclusion

There is evidence that corruption is at least partly due to cultural elements. Not in every country does the public opinion conceive corruption - at least small-scale corruption - as negative. Sentences like "I was corrupt but so was everybody else" reveal that a generally corrupt environment can serve as a justification for one's own corrupt behaviour.

The present paper captures some cultural aspects of corruption. An agent is corrupt if corruption maximizes utility. However, utility is not only affected by purely monetary rewards but also by the presence (or absence) of moral costs if engaging in corrupt activities. In the model remunerations were chosen such that an agent is either always honest or always corrupt. Analyzing this extreme case allows to single out the purely educational effects on corruption levels. In order to do so it was assumed that new-born agents had to form their preferences and were influenced by the education effort exerted by their parent as well as by the general corruption level of society. Parents care about their children and judge their children's utility as if it were their own. The resulting dynamics had the realistic feature that the lower the proportion of a given type the higher its education effort. This feature keeps the steady state off the boundary and avoids a complete elimination of corrupt (or honest) agents.

Taking the model seriously implies that corruption will never be eliminated completely, a view which is also expressed by Klitgaard (1988). Indeed, there is no country without corruption although corruption levels vary widely across countries even with similar economic characteristics. The present model found two steady states one with a low and one with a high level of corruption in an otherwise identical economy. This shows the strength of cultural elements in determining the actual corruption levels of a society and implies that two countries with the same level of development and the same institutions against corruption may have drastically different levels of corruption depending on the initial state of the society. In the high corruption steady state the public reputation outweighs individual reputation and thereby locks society into highly corrupt behaviour. In the low corruption steady state individual reputation is decisive.

Controlling corruption imposes a cost on society. Individual behaviour has to be

monitored. If monitoring is common and the technique is reliable, it pays less to be corrupt. This is also true for high fines. Both the present model and models concentrating purely on monetary rewards share this desirable feature. The advantage of the present approach is that it entails additional policy implications which can be cost-saving in the long run. High fines and high monitoring work only as long as they are implemented. If, however, young generations are educated to adapt a moral attitude against corruption, monitoring can be reduced while low corruption levels are preserved. Educating the young is the key element in reducing corruption successfully.

References

- AKERLOF, G. (1983). "Loyalty Filters," *American Economic Review*, **73**, 54-63.
- ANDVIG, J.C. AND K. MOENE (1990). "How Corruption May Corrupt," *Journal of Economic Behavior and Organization*, **13**, 63-76.
- ARROW, K.J (1984) "The place of Moral Obligations in Preference Systems", in Arrow *Collected Papers of Kenneth J. Arrow*, Blackwell
- BESLEY, T. AND MCLAREN, J. (1993). "Taxes and Bribery: The Role of Wage Incentives," *Economic Journal*, **103**, 119-141.
- BISIN, AND VERDIER (1996). "The Economics of Cultural Transmission and the Dynamics of preferences," mimeo, MIT.
- BOYD, R. AND RICHERSON, P. (1985). *Culture and the Evolutionary Process*, University of Chicago Press, Chicago
- BLOCK, M.K. AND HEINEKE, J.M. (1975). "A Labour Theoretical Analysis of Criminal Choice," *American Economic Review*, **65**, 314-325.
- CAVALLI-SFORZA, L. (1996). *Geni, popoli e lingue*. Adelphi Edizioni, Milano
- CAVALLI-SFORZA, L. AND FELDMAN, M. (1981). *Cultural Transmission and Evolution*. Princeton University Press, Princeton.
- CHINN, D. (1978). "Farmer Response to Good Grain Controls in Developing Countries," *Quarterly Journal of Economics*, **92**, 697-703.
- CLARK, D. (1987). "A community relations approach to corruption: the case of Hong Kong," *Corruption and Reform*, **2**, 135-257
- CLARK, D. (1989). "Mobilizing public opinion against corruption: a commentary," *Corruption and Reform*, **4**, 123-129.
- COURSEY D.L, E. HOFFMAN AND M. SPITZER (1987). "Fear And Loathing in the Coase Theorem: Experimental Evidence Involving Physical Discomfort" *Journal of Legal Studies*, **16**, 217-248.

- FRANK, R.H. (1988). *Passion Within Reason: The Strategic Role of Emotions*. New York: Norton and Company
- KLITGAARD, R. (1988). *Controlling corruption*. University of California Press, Berkeley.
- LEBRAS, H. AND E. TODD. (1981). *L'invention de la France: Atlas Anthropologique et Politique*, Livre de Poche, Hachette, Paris.
- QIZILBASH, MOZAFFAR (1994). "Corruption, Temptation and Guilt: Moral Character in Economic Theory," Discussion Paper No. 9419, University of Southampton.
- ROSE-ACKERMAN, S. (1978). *Corruption: A Study in Political Economy*. Academic Press
- TIROLE, J. (1996). "A theory of collective reputation (with applications to the persistence of corruption and firm quality," *Review of Economic Studies*, **63**, 1-22.

APPENDIX

Proof of Lemma 1

$$F'(q) = 1 + (1 - \lambda)(1 - 2q)(\tau^a(q) - \tau^b(q)) - (1 - \lambda)q(1 - q) \left[\frac{V^{aa} - V^{ab}}{C''(\tau^a(q))} + \frac{V^{bb} - V^{ba}}{C''(\tau^b(q))} \right] \quad (26)$$

substituting (8) and (9) in (26)

$$F'(q) = 1 + (1 - \lambda)(1 - 2q)(\tau^a(q) - \tau^b(q)) - (1 - \lambda) \left[\frac{qC'(\tau^a(q))}{C''(\tau^a(q))} + \frac{(1 - q)C'(\tau^b(q))}{C''(\tau^b(q))} \right]$$

Evaluating $F'(q)$ in q^* we get

$$F'(q^*) = 1 - (1 - \lambda) \frac{C'(\tau^*)}{C''(\tau^*)} \in (0, 1)$$

where $\tau^* = \tau^a(q^*) = \tau^b(q^*)$. By the mean value theorem

$$F(q) - q^* = F(q) - F(q^*) = (q - q^*)F'(c)$$

for some $c \in [\min\{q, q^*\}, \max\{q, q^*\}]$. For c sufficiently close to q^* , $0 < F'(c) < 1$ and

$$|F(q) - q^*| < |q - q^*|$$

$q_{t+1} = F(q_t)$ is closer to q^* than q_t .

Similarly, $F'(0) > 1$ and $F'(1) > 1$ and, by the mean value theorem, $|F(q) - 0| > |q - 0|$ and $|F(q) - 1| > |q - 1|$. We conclude that q^* is stable and $q = 0$ and $q = 1$ are unstable. \square

Proof of Proposition 1. $\tilde{q} < \underline{q} < \bar{q}$ by (12). Assume without loss of generality that $q_0 < \tilde{q}$.

Part 1.1. Consider the expected policy profile $\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}$. Observe that

$$\tilde{q} < \underline{q} < \underline{q} + \lambda^{T-t-1}(\bar{q} - \underline{q}) + \lambda^{T-t-1}\alpha(1-\lambda)(\bar{B} - b).$$

By lemma (2) $\tau_t^a(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_{z=T}^\infty\}) > \tau_t^b(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_{z=T}^\infty\})$, for all t such that $q_t < \tilde{q}$, and $F(q_t) > q_t$, by (10), for all such q_t . There exists a $w > 0$ such that $q_w \leq \tilde{q} \leq F(q_w)$. Let w be equal to $T-1$.

Part 1.2. The expected policy at $T-1 = w$ is $\{\sigma^s\}_{z=T}^\infty$ and $\tau_t^a(\{\sigma^s\}_{z=T}^\infty) > \tau_t^b(\{\sigma^s\}_{z=T}^\infty)$ for all $q_t < \bar{q}$ by lemma (1). Furthermore,

$$V_t^{aa}(\{\sigma^s\}_{t+1}^\infty) - V_t^{ab}(\{\sigma^s\}_{t+1}^\infty) = \frac{e + \lambda\alpha(\bar{B} - \bar{b}) - (\bar{B} - B)}{1 - \lambda} > 0,$$

$$V_t^{bb}(\{\sigma^s\}_{t+1}^\infty) - V_t^{ba}(\{\sigma^s\}_{t+1}^\infty) = \frac{(\bar{B} - B) - \lambda\alpha(\bar{B} - \bar{b})}{1 - \lambda} > 0,$$

and

$$\frac{V_t^{aa}(\{\sigma^s\}_{t+1}^\infty) - V_t^{ab}(\{\sigma^s\}_{t+1}^\infty)}{V_t^{aa}(\{\sigma^s\}_{t+1}^\infty) - V_t^{ab}(\{\sigma^s\}_{t+1}^\infty) + V_t^{bb}(\{\sigma^s\}_{t+1}^\infty) - V_t^{ba}(\{\sigma^s\}_{t+1}^\infty)} = q^* = \bar{q}.$$

\bar{q} is asymptotically stable by lemma (1). Observe that $\sigma(q_{t+1})_{t \geq 0} = \{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}$.

2. $\underline{q} < \bar{q} < \tilde{q}$ by (12). Assume without loss of generality that $q_0 > \tilde{q}$.

Part 2.1. Consider the expected policy profile $\{\{\sigma^s\}_{t+1}^{T-1}, \{\sigma^p\}_T^\infty\}$. Observe that

$$\tilde{q} > \bar{q} > \bar{q} - \lambda^{T-t}(\bar{q} - \underline{q}).$$

By lemma 2 $\tau^a(\{\{\sigma^s\}_{t+1}^{T-1}, \{\sigma^p\}_T^\infty\}) < \tau^b(\{\{\sigma^s\}_{t+1}^{T-1}, \{\sigma^p\}_T^\infty\})$ for all t such that $q_t > \tilde{q}$, and $F(q_t) < q_t$, by (10), for all such q_t . There exists a $z > 0$ such that $q_z \geq \tilde{q} \geq F(q_z)$. Let z be equal to $T-1$.

Part 2.2. The expected policy at $T-1 = z$ is $\{\sigma^p\}_T^\infty$ and $\tau^a(\{\sigma^p\}_{t+1}^\infty) < \tau^b(\{\sigma^p\}_{t+1}^\infty)$ for all $q_t > \underline{q}$ by lemma 1. Furthermore,

$$V^{aa}(\{\sigma^p\}_{t+1}^\infty) - V^{ab}(\{\sigma^p\}_{t+1}^\infty) = \frac{e - (\bar{b} - b)}{1 - \lambda} > 0,$$

$$V^{bb}(\{\sigma^p\}_{t+1}^\infty) - V^{ba}(\{\sigma^p\}_{t+1}^\infty) = \frac{(\bar{b} - b)}{1 - \lambda} > 0 \quad \text{and}$$

$$\frac{V^{aa}(\{\sigma^p\}_{t+1}^\infty) - V^{ab}(\{\sigma^p\}_{t+1}^\infty)}{V^{aa}(\{\sigma^p\}_{t+1}^\infty) - V^{ab}(\{\sigma^p\}_{t+1}^\infty) + V^{bb}(\{\sigma^p\}_{t+1}^\infty) - V^{ba}(\{\sigma^p\}_{t+1}^\infty)} = q^* = \underline{q}.$$

\underline{q} is asymptotically stable by lemma 1. Observe that $\sigma(q_{t+1})_{t \geq 0} = \{\{\sigma^s\}_{t+1}^{T-1}, \{\sigma^p\}_T^\infty\}$.

3. Parts 1.2 and 2.2 apply to (a) and (b), respectively. \square

Proof of Lemma 3. From lemma 2 $\tau^a(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\}) > \tau^b(\{\{\sigma^p\}_{t+1}^{T-1}, \{\sigma^s\}_T^\infty\})$ when

$$q_t < \underline{q} + \lambda^{T-t-1}(\bar{q} - \underline{q} + \alpha(1-\lambda)\frac{\bar{B} - \bar{b}}{e}) \equiv \hat{q}(T, t)$$

$$\lim_{T \rightarrow \infty} \hat{q}(T, t) = \underline{q} \quad \text{and} \quad \frac{d\hat{q}(T, t)}{dt} > 0$$

$$\Delta q_t = q_t(1 - q_t)(1 - \lambda) \left[\left(\frac{(V_t^{aa}(k) - V_t^{ab}(k))(1 - q_t)}{\beta} \right)^{\frac{1}{\beta-1}} - \left(\frac{(V_t^{bb}(k) - V_t^{ba}(k))q_t}{\beta} \right)^{\frac{1}{\beta-1}} \right]$$

which can be written as

$$\Delta q_t = q_t(1 - q_t)(1 - \lambda) \left[\left(\frac{e\hat{q}(T, t)(1 - q_t)}{(1 - \lambda)\beta} \right)^{\frac{1}{\beta-1}} - \left(\frac{e(1 - \hat{q}(T, t))q_t}{(1 - \lambda)\beta} \right)^{\frac{1}{\beta-1}} \right]$$

By the concavity of $x^{\frac{1}{\beta-1}}$

$$\Delta q_t \leq \frac{(1 - q_t)(1 - \lambda)\tau_t^b(\sigma^p, \sigma^q)}{(1 - \hat{q}(T, t))(\beta - 1)}(\hat{q}(T, t) - q_t)$$

$$\frac{(1 - q_t)(1 - \lambda)}{(1 - \hat{q}(T, t))} \leq \frac{(1 - \underline{q})(1 - \lambda)}{(1 - \underline{q} - \lambda(\bar{q} - \underline{q} + \alpha(1 - \lambda)\frac{\bar{B} - \bar{b}}{e}))} \quad \text{for all } t \leq t'$$

and

$$\frac{(1 - \underline{q})(1 - \lambda)}{(1 - \underline{q} - \lambda(\bar{q} - \underline{q} + \alpha(1 - \lambda)\frac{\bar{B} - \bar{b}}{e}))} \leq 1$$

when $\alpha \leq \frac{\bar{B} - B}{\bar{B} - \bar{b}}$. Therefore,

$$\Delta q_t < (\hat{q}(T, t) - q_t)$$

and $q_t < \hat{q}(T, t)$, for all $t < T$. □